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Effect of pulps cooking of local plantain cultivars (*Musa sp.*) from Côte d'Ivoire on the functional properties of the resulting flours

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ABSTRACT

Functional properties of raw and cooked pulp flours from five local cultivars of plantain (*Musa sp*.) were studied to evaluate their potential in food systems. The pulps were subjected to different boiling times (10, 15 and 20 min). Swelling power, solubility, dispersibility, foaming capacity and stability of the foam, water and oil absorption capacity of these different flours were determined according to standard methods. Results show that the flours from the boiled pulps have the highest rates of swelling, solubility, dispersibility, water absorption capacity and oil content compared to flours from raw pulps. In contrast, flours from boiled pulps foam less. Flours of the *Afoto* cultivar have the highest rates of swelling (17.03 to 19.21 g of water / g of flour), solubility (16.98 to 21.02%), water absorption capacity (288.06 to 398.99%), oil absorption capacity (93.23 to 103.63%) and foaming capacity (15.46 to 8.72%). Overall, pulp cooking of these plantain cultivars has a positive effect on the functional properties of the resulting flours.

KEYWORDS: Cooked pulps, cooking time, cultivar, fonctional properties, flours, plantain, raw pulps,

INTRODUCTION

Plantain is one of the world's major food resources with production of nearly 38 million tonnes [1]. In the tropical and subtropical regions of East, Central and West Africa, Southeast Asia, Central America and the Southern Caribbean, plantain production is a key activity contributing food security and job creation [2]. It allows the diversification of the incomes of the populations in the rural and urban areas as well as the improvement of the gross domestic product (GDP), which also participates in the fight against poverty [3 ; 4]. In Côte d'Ivoire, plantain production is estimated at nearly 1.6 million tonnes [1]. However, the problem of the fresh preservation of plantain remains an obstacle for a better valorization of the production and the use of this food. It is used most often to make various traditional dishes for immediate consumption such as *foutou*, *foufou*, *aloco*, *akpessi*, *locloun* and *apity* [5 ; 6]. The processing of plantain pulp into flour could help promote its production and use in the food industry. In Côte d'Ivoire, several local plantain cultivars, which have not yet been the subject of post-harvest scientific studies, were collected in the local village plantations by breeding geneticists of the National Center for Agronomic Research (CNRA). The valorization of these local cultivars, already anchored in the food habits of the populations for decades is necessary. This work aims to determine the effect of cooking time on the functional properties of flours from the raw and boiled pulps of five local plantain cultivars in order to explore their use in the food industries.

MATERIAL AND METHODS

Sample collection, preparation and treatment

Plantains (*Musa sp.*) were collected from the experimental plot of National Center of Agronomic Research (CNRA) of Azaguié (situated 50 km of north of Abidjan) in Côte d’Ivoire. Fruits were harvested at traditional cut, that is, when one of the fingers of the regime begins to turn yellow or when a crack appears on one of the fingers of the diet. Forty (40) freshly harvested green fruits were used per cultivar and divided into four (4) parts of ten (10) fruits. The fruits were washed with clean tap water and peeled. The pulps of three parts were cut into a 3 cm thick slice. Pulps cut from the first part were fired at 100 °C for 10 min (FPC 10), 15 min (FPC 15) for those of the second part and 20 min (FPC 20) for those of the third part. Then, the pulps of the fourth part (FPF) and the boiled pulps of the three parts were cut into slices of 1 cm thick and placed in the oven at 45 °C for 2 days. The dried slices were pulverized by grinding, passed through a 200u sieve and stored in airtight containers for analysis.

Functional properties evaluation

Flour dispersibility

The flour dispersibility was determined by the method described by Kulkarni *et al* [7]. 1 g of flour were weighed into 10 ml measuring cylinder and distilled water added to make a volume of 10 ml. The mixture was stirred vigorously for 2 min. The volume of the settled particles was registered after regular time step of 30 min. The volume of the settled particles was subtracted from 10. The difference was reported as percentage of dispersibility.

Water absorption capacity

The water absorption capacity (WAC) of plantain (*Musa sp.*) pulp flours were evaluated according to Phillips *et al* [8] and Anderson *et al* [9] methods respectively. 1 g of flour samples (M_0) was each weighed into a centrifuge tube and 10 ml distilled water added. This mixture was shaken for 30 min in a KS 10 agitator and then kept in a water bath at 37 °C for 30 min. It was then centrifuged (Sigma-Aldrich, 2-16PK, Osterode, Germany) at 15,000 rpm for 15 min. The resulting sediment (M_2) was weighed and then dried at 105 °C to constant mass (M_1). The water absorption capacity was calculated from the following relationship:

$$WAC\ (\%) = \frac{(M_2 - M_1)}{M_1} \times 100$$

Oil absorption capacity

The oil absorption capacity (OAC) of plantain (*Musa sp.*) flours was evaluated according to Eke and Akobundu [10] methods. 1 g of sample (M_0) was mixed with 10 ml of oil. The slurry was agitated on a Vortex mixer for 2 min, allowed to stand at room temperature (28 °C) for 30 min and then centrifuged at 15,000 rpm for 10 min. The resulting sediment was weighed (M_1). The oil absorption capacity was calculated from the following formula:

$$OAC\ (\%) = \frac{(M_1 - M_0)}{M_0} \times 100$$

Foam capacity and foam stability

The foam capacity (FC) and stability (FS) of plantain (Musa sp.) flours were studied by the method of Coffman and Garcia [11]. 3 g of flour was transferred into clean, dry and graduated (50 mL) cylinders. The flour samples were gently leveled and 30 mL distilled of water was added to each sample to facilitate the dispersion of the flour. The cylinder was swirled and allowed to stand for 120 min while the change in volume was recorded every 10 min. The FC (%) and FS (%) values were calculated as follows:

$$FC\ (\%) = \frac{V_1 - V_0}{V_0} \times 100$$

V_0: Volume before homogenization (mL)

V_1: Volume after homogenization (mL)

$$FS\ (\%) = \frac{Vt}{Vi} \times 100$$

***Vi**: Initial volume of the foam*

Swelling Power (SP) and Solubility

The effect of temperature on swelling and solubility was carried according to the method of Adebooye and Singh [12]. 1 % of flour suspension was prepared in test tubes and put in a water bath at different temperatures (50 °C to 95 °C) at 5 °C intervals with maximum stirring for 1 h. The suspensions contained in tubes were centrifuged at 15,000 rpm for 15 min. The resulting sediment (Wcu) and the supernatants were collected in different containers, weighed and oven-dried at 105 °C for 24 h for the supernatant and 48 h for the resulting sediment. Their respective masses were then determined after drying (Ecu and Esu respectively). The supernatants were used to determine the solubility (S) and the resulting sediment for the swelling index (Sw) according to the following formulas:

$$S\ (\%) = 100 \times (E_{su} - W_{co}) / W_i$$

$$Sw\ (g/g) = (W_{cu} - E_{cu}) / (E_{cu} - W_{co})$$

With:

***S (%)**: solubility expressed as a percentage (%)*

***Sw (g of water / g of flour)**: swelling power (g of water / g of flour)*

***Esu**: mass of the crucible + supernatant after steaming (g)*

***Wco**: mass of the empty crucible (g)*

***Wi**: test sample of the flour (g)*

***Mcu**: mass of the crucible + base (g)*

***Ecu**: mass of the crucible + base after steaming (g)*

Statistical analyses

All analyses were carried out in triplicates. Statistical significance was established using one-way analysis of Variance (ANOVA) models to estimate the effect of treatment on functional properties of flours from plantain (*Musa sp*.) pulp at 5% level. Means were separated according Tukey's (HSD) test at $P < 0.05$, with the help of the software.

RESULTS AND DISCUSSION

Swelling power of flours

The results evolution of the swelling of the different plantain flours (Fig. 1) showed that the swelling power of flours from raw pulps is low compared to that of flours from cooked pulps and these swelling powers are all the greater as the duration of cooking the pulp from which the flour is derived is high. Flours from *Afoto* cultivars have the highest swelling power regardless of the type of flour. The swelling rates for this cultivar range from 1.66 to 6.04 g of water/g of flour at the end of the first phase between 50 °C and 60 °C. Then they change from 14.01 to 17.45 g of water / g of flour at the end of the second phase between 60 °C and 80 °C. Finally, at the end of the last phase between 80 °C and 95 °C, the swelling rates of flours of the same cultivar vary from 17.03 to 19.21 g of water / g of flour. Indeed, the swelling power is an indication of the absorption index of the starch granules during heating [13]. Since plantain are starch products, the variation in starch grain swelling power from one cultivar to another may be due to the difference in hydration of the starch grains, which is largely affected by the structural arrangements of their amylose and amylopectin. The difference in the degree of organization of hydroxyl groups to form hydrogen and covalent linkages between starch amylose and amylopectin chains could also explain the difference in flour swellings between cultivars [14]. This difference in swelling between the flours of the raw samples and those of the cooked samples is explained by the fact that the cooked pulp have already undergone a pregelatinization of their starch during boiling. This increases the starch water binding capacity of these flours [15].

Solubility of flours

The evolution of the solubility of flours from raw pulps and flours from the boiled pulps of local plantain cultivars was measured as a function of temperature (Fig. 2). The result indicated that the flours from raw pulps are less soluble in water than those from boiled pulps. In addition, the solubility of the flours from the boiled pulps is all the higher as the cooking time of the pulps from which it is derived is prolonged. At the end of a first phase ranging from 50 to 65 °C the highest solubility rates are obtained by the different flours of *Afoto* cultivar with respective values of 5.61 % (FPF), 6.94 % (FPC10), 7.95 % (FPC15), 8.13 %

(FPC20). This phase is characterized by a very low solubility of the different flours and corresponds to integration period of water into the flour [16]. The different flours of the same cultivar (*Afoto*) recorded the highest solubility rates up to 95 °C with respective values of 16.98 % (FPF), 19.16 % (FPC10), 20.06 % (FPC15), 21.02 % (FPC20). Like the swelling, the solubility of the flours of these plantain cultivars increases with temperature. In fact, the solubility becomes high when the starch granules of the flours swollen under the effect of the temperature explode and release the amylose [17].

Flours dispersibility

The flours from the boiled pulps (FPF) have the highest dispersibility rates compared to the flours from the raw pulps (FPC) as shown in Fig. 3. Dispersibility of raw flours of *Attiébana* cultivar increases rapidly up to 60 min (35 %) while that of other cultivars is rapid up to 30 min. After 30 min, the dispersibility of the flours from the raw pulp (FPF) of *Attiébana* cultivar (25 %) is the highest. The dispersibility of raw flour (FPF) subsequently slowed down before stabilizing after 150 min. At this stage, the raw flour of the cultivar *Attiébana* (55 %) has the highest dispersibility whereas that of the cultivar *Ataplègnon* (42.50 %) is the lowest. For flours from the boiled pulps, dispersibility increases rapidly to 30 min for all cultivars before slowing down and becoming stable after 150 min. At 30 min, the dispersibility rates of flour FPC10 (39.96 %) and FPC15 (42.19 %) of cultivar *Attiébana* are the highest while those of flour FPC20 cultivars, *Attiébana*, *Afoto*, *Banadié*, and *Banaboi*, 50.00 %. After 150 min, the dispersibility rates of flour FPC10 (63.11 %) and FPC15 (69.83 %) of the *Attiébana* cultivar and those of FPC20 flour (77.50 %) of the *Afoto* cultivar are the highest. At the end of the process (180 min), the dispersibility rates of the flours FPF (55.01 %), FPC10 (65.39 %) and FPC15 (75.25 %) of *Attiébana* cultivar and those of the FPC20 flours (77.50 %) of the *Afoto* cultivar are the highest. Indeed, the dispersibility of flours is an indicator of their ability to reconstitute in water. It is a useful functional parameter in the formulations of various food products [7]. The high dispersibility of the flours from the boiled pulps is due to the gelatinization of the starch which occurs during the cooking of the pulps. In this state, the water binding capacities of the starch grains increase [18]. Indeed, the increase in the dispersibility of the flours makes it possible to obtain a fine and coherent paste with emulsifying properties observed during the manufacture of bread, pasta and biscuits [19 ; 20]. Therefore, the flours from the boiled pulps of the plantain cultivars studied can be used in pastry and bakery, especially that of the *Attiébana* and *Afoto* cultivars.

Foaming capacity and stability of the foam

The foaming capacity of flours from raw pulps (FPF) and those from boiled pulps (PFC) are generally low for all cultivars as shown in the Table. In addition, it decreases significantly ($p <0.05$) as the cooking time of the pulp increases. The foaming capacities of flours from raw pulps (FPF) range from 8.88 % (*Banablé*) to 15.46 % (*Afoto*). The foaming capacity of FPF flours of *Ataplègon* (10.89 %) and *Banaboi* (10.53 %) did not differ significantly ($p \geq 0.05$). For flours from boiled pulps (FPC), the highest foams produced by FPC10 (9.15 %), FPC15 (8.92 %) and FPC20 (8.72 %) are obtained by *Afoto* cultivars. Indeed, the capacity of the flour to produce foam is related to its content of soluble proteins that can migrate rapidly in the continuous phase and to be able to unfold very quickly so as to easily adsorb at the gas interface / liquid [21]. According to Aluko and Yada [22], a good flexibility of the protein allows it to spread more rapidly at the air-water interface, to encapsulate the particles of air and then to improve the formation of foam. The foams produced are less stable for flours from boiled pulps (Fig 4). This instability of the foam is accentuated when the cooking time of the pulps is prolonged. After a sharp decline in the foams level of FPF flours for 20 min, they stabilize thereafter up to 120 min with rates between 17.50 % (*Banaboi*) and 51.67 % (*Afoto*). As for the FPC10, FPC15 and FPC20 flours, the foams stabilize after a rapid drop in rates in 30 min. At 120 min, the foam stability rates of FPC10, FPC15 and FPC20 flour are respectively between 3.45 % (*Attiébana*) and 16.02 % (*Afoto*), between 2.36 % (*Attiébana*) and 11.19 % (*Afoto*), then between 1.33 % (*Banished*) and 7.95 % (Afoto). Indeed, the stabilization of the foam produced is all the greater as the protein film at the gas / liquid interface is thicker, cohesive, elastic, continuous and impervious to gas. It also depends on the secondary or tertiary conformation of the protein [23 ; 24] and requires the ability of proteins to resist mechanical and gravitational stresses. Foam formation and stability is a function of the type of protein and its concentration, degree of denaturation, pH, ions, treatment processes, viscosity and surface tension [25]. Food ingredients that can sufficiently foam and stabilize the foam can be used in bakery products [26]. The low foaming capacity of flours from boiled pulps and the low stability of their foams are due to the denaturation of proteins during pulp cooking because heat breaks the bonds that maintain the secondary and tertiary structures of proteins [27].

Water Absorption Capacity

Water and oil Absorption Capacities, and the hydrophilic / lipophilic ratio are shown in the Table. Regarding the water absorption capacity of flours, they increase significantly ($p <0.05$) according to the duration of cooking of the pulp. The highest proportions of water absorbed by the different flours FPF (288.06 %), FPC10 (389.48 %), FPC15 (392.25 %) and FPC20 (398.99 %) are obtained by the cultivar *Afoto*. FPF flours of cultivars *Banaboi* (266.39 %) and *Attiébana* (263.07 %) showed no significant difference ($p \geq 0.05$). For FPC10 flours, only *Attiébana* (359.57 %) and *Banablé* (358.55 %) did not differ significantly ($p \geq 0.05$). For FPC15 flours, *Ataplègnon* (385.25 %) and *Banaboi* (386.52 %) are identical ($p \geq 0.05$). FPC20 flours of cultivars *Ataplègnon* (387.03 %) and *Banaboi* (389.30 %) are also identical ($p <0.05$). Indeed, the water absorption capacity of a flour is its ability to trap large amounts of water through its particles, so that exudation is prevented [28]. It is an index that determines the quality and texture of certain food products. It plays an important role in the food preparation process because it influences certain functional and sensory properties [29]. In addition, the use of flour as a food ingredient depends on its interaction with water [29]. It is a factor in the stability of foods against some effects such as syneresis that sometimes occurs during autoclaving and freezing [30]. In addition, water absorption capacity is important in cooking and ensures consistent swelling of the product [31]. Moreover, the variation of the water absorption capacity of a flour can be attributed to the quantity of intact starch granules, the difference in protein structures, the lipid content and the presence of different carbohydrates hydrophilic [32]. Flours with high water absorption capacity tend to have more polysaccharides and hydrophilic proteins [33 ; 25]. The increase in the water absorption capacity in the flours of the cooked pulps would be related to the gelatinization of the starch. This phenomenon increases the binding capacity of water and makes the product more digestible [18 ; 34]. This increase in the water absorption capacity of cooked flour could make them good bakery ingredients for bread making. In fact, a high water absorption capacity makes it possible to add more water to the dough, thus improving its handling and keeping the bread fresh. In addition, the water absorption capacity is an essential property of proteins in viscous foods such as soups, pasta, creams and bakery products as it allows the flour to absorb water without however dissolve protein, thereby thickening and increasing the viscosity of food [29].

Like the water absorption capacity, the oil absorption capacity of these flours increases significantly ($p <0.05$) depending on the pulp cooking time. The highest proportions of oil absorbed by the flours FPF (93.23 %), FPC10 (98.48 %), FPC15 (100.62 %) and FPC20 (103.63 %) are recorded at the *Afoto* variety. However, the oil capacities absorbed by the FPF flours of the *Afoto* (93.23 %) and *Banablé* (92.93%) cultivars on the one hand and those absorbed by the FPC10 flours of the *Banablé* cultivars (95.17%) and *Atiébana* (94.20 %), on the other hand, did not show a significant difference ($p \geq 0.05$). Likewise, the oil absorption capacities of FPC15 and FPC20 flours of *Afoto* and *Banablé* cultivars did not differ significantly ($p \geq 0.05$). Indeed, the high capacity of certain oil-absorbing flours such as those of the *Afoto* and *Banablé* cultivars is due to the presence of large amounts of side chains of apolar amino acids [35] and also to the presence of lipophilic groups [36], which tends to bind fats. Oil absorption is an important property in the development of food products because it influences the flavor and sensation of food in the mouth [31]. The ability of a food component to trap oil is an important feature in fatty food formulations [37 ; 38]. The interactions between oil and flour are very important in food systems because of their effects on the nutritional value and texture of food [39]. Flours with high oil absorption capacity can be used in the preparation of donuts, the formulation of ground meat, soft biscuits in which the oil holding capacity is paramount [40].

The hydrophilic-lipophilic ratio is the ratio of the water absorption capacity to the oil absorption capacity and makes it possible to evaluate the comparative affinity of the flours for water or for oil [41]. The highest values of the hydrophilic-lipophilic ratios of the FPF (3.83), FPC10 (4.10), FPC15 (4.62) and FPC20 (4.48) flours are those of the *Ataplègnon* cultivar. These ratios are all the higher as flour has a greater affinity for water than for oil. The values obtained in this study are much higher than those reported by Njintang *et al* [41] for cowpeas (about 1.12) used as an ingredient in "koki", a traditional cake made from an emulsion of palm oil, water and cowpea paste. This indicates that the flours of these plantain cultivars could be used for this type of cake.

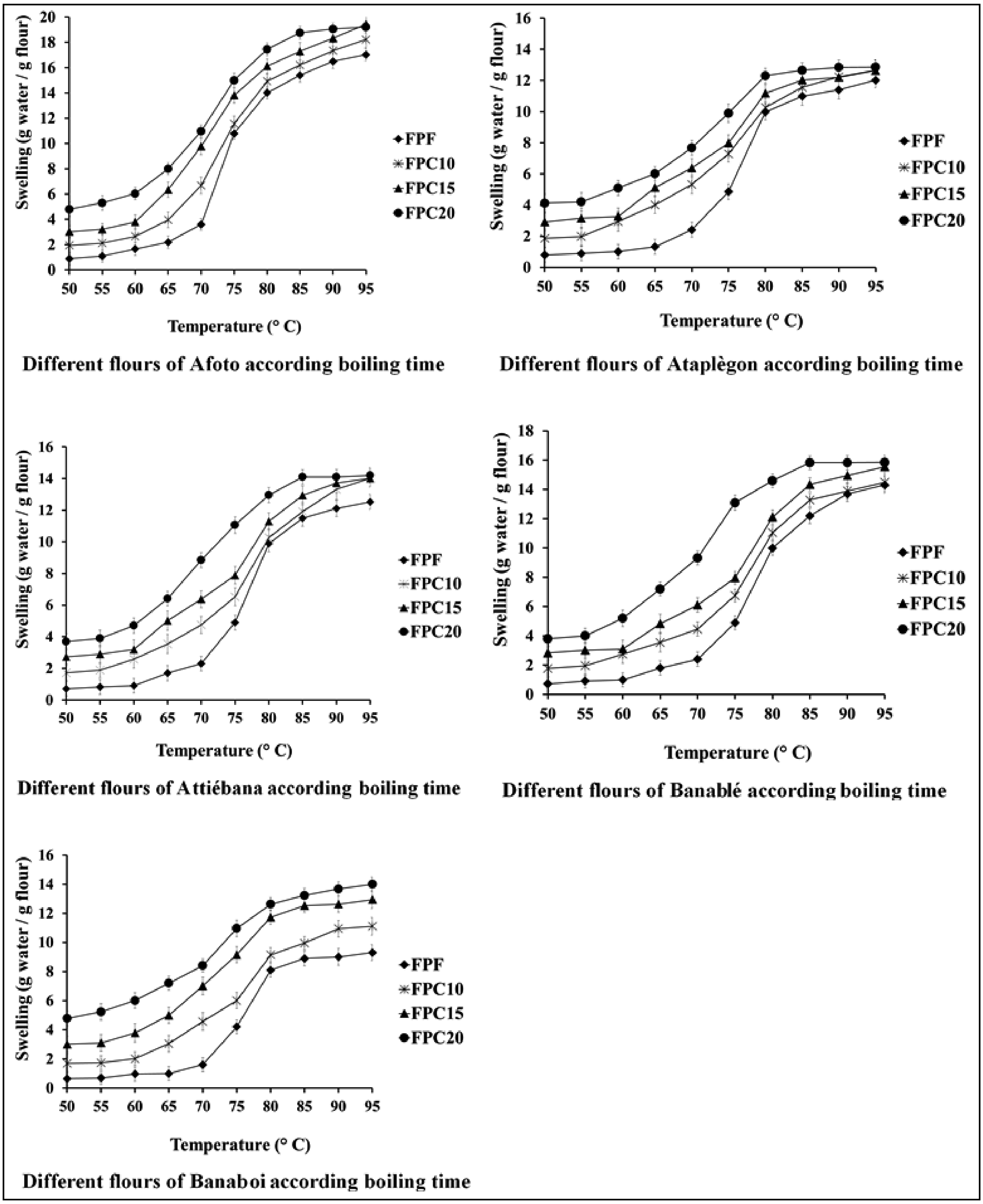

Figure 1 Swelling of flours from local plantain cultivars (*Musa sp.*)

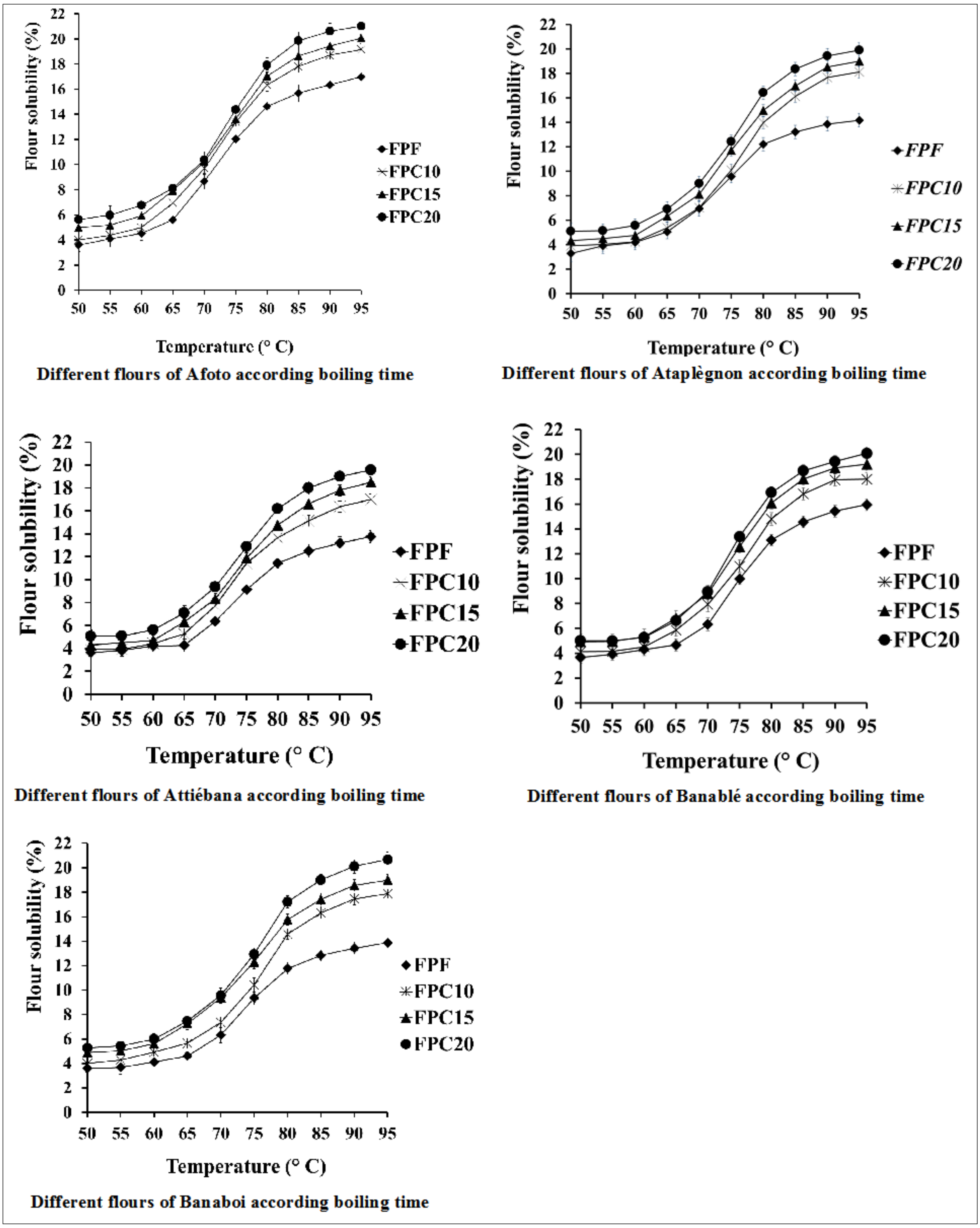

Figure 2 Solubility of flours from local plantain cultivars (*Musa sp.)*

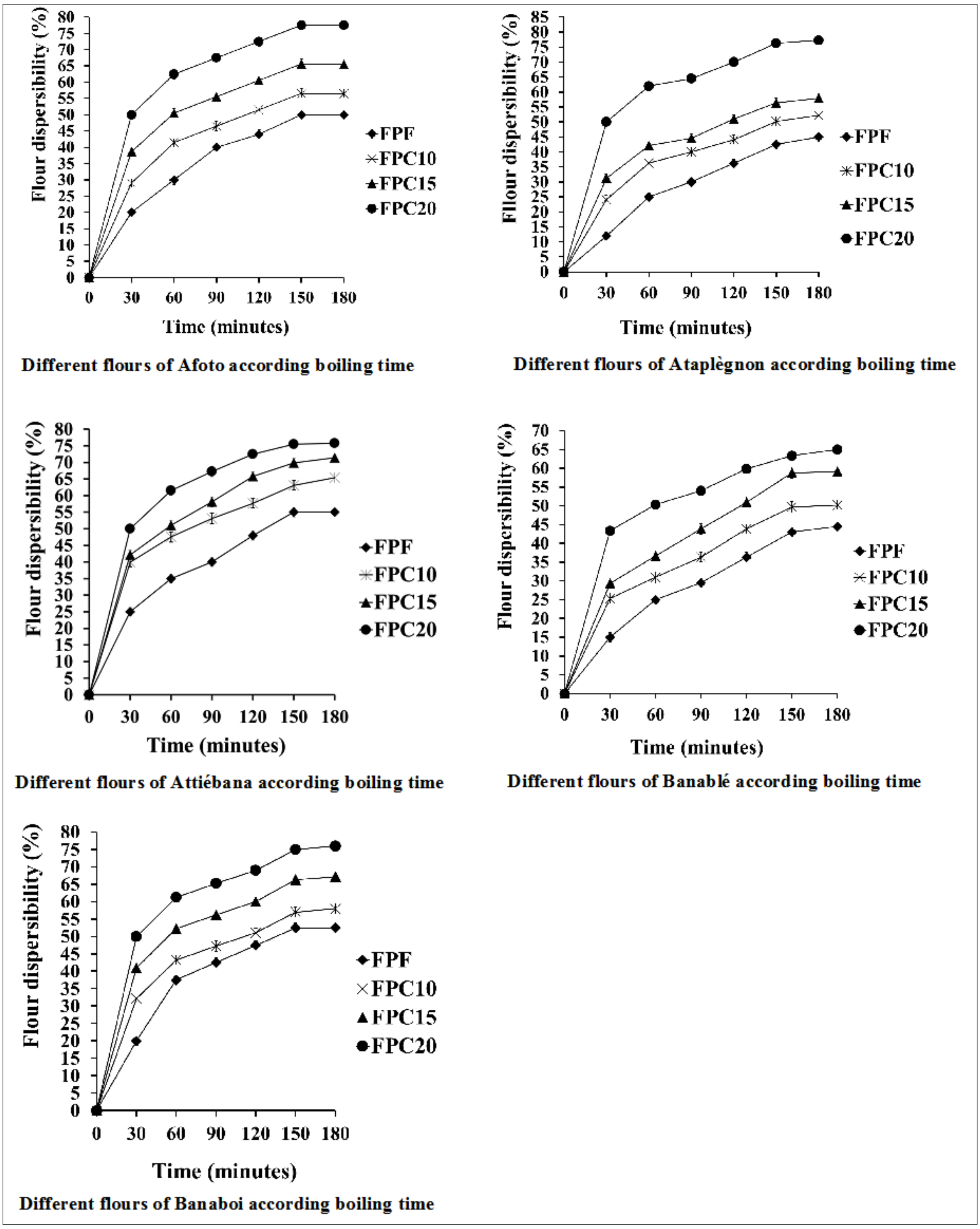

Figure 3 Dispersibility of flours from local plantain cultivars (*Musa sp.)*

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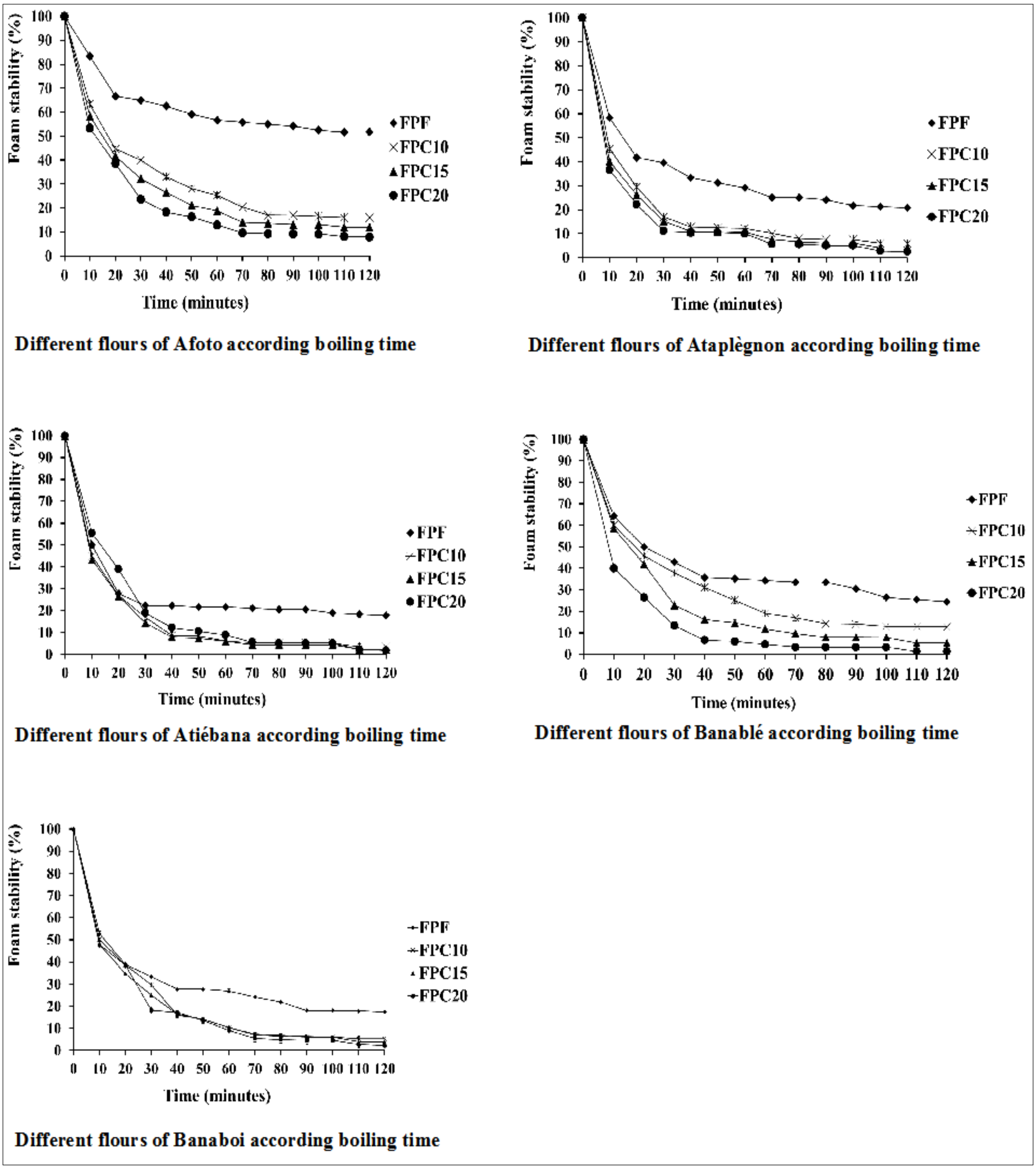

Figure 4 Stability of the moss of flours from local plantain cultivar (*Musa sp.)*

Table Absorption capacity of water and oil, foaming capacity and hydrophilic/lipophilic ratio of flours from local plantain cultivars (*Musa spp.*)

	Boiling time (min)	*Afoto*	*Ataplègnon*	*Attiébana*	*Banablé*	*Banaboi*
CAE (%)	FPF	288.06 ± 0.11^{aD}	279.22 ± 0.39^{bD}	263.0.7 ± 0.36^{cB}	234.05 ± 1.11^{dB}	266.39 ± 1.06^{cD}
	FPC10	389.48 ± 0.42^{aC}	333.27 ± 0.62^{dC}	359.57 ± 0.51^{cC}	358.55 ± 0.50^{cA}	374.04 ± 0.61^{bC}
	FPC15	392.25 ± 0.31^{aB}	385.25 ± 0.56^{bB}	359.31 ± 0.83^{dC}	361.50 ± 0.49^{cA}	386.52 ± 0.48^{bB}
	FPC20	398.99 ± 0.25^{aA}	387.03 ± 0.80^{bA}	365.30 ± 0.31^{cA}	355.51 ± 0.61^{dA}	389.30 ± 0.92^{bA}
CAH (%)	FPF	93.23 ± 0.74^{aD}	72.96 ± 0.70^{dD}	88.95 ± 0.71^{bD}	92.93 ± 0.25^{aD}	84.11 ± 0.59^{cD}
	FPC10	98.48 ± 0.74^{aC}	81.21 ± 0.70^{dC}	94.20 ± 0.93^{bC}	95.17 ± 0.42^{bC}	90.38 ± 0.95^{cC}
	FPC15	100.62 ± 0.61^{aB}	83.35 ± 0.68^{dB}	96.34 ± 0.96^{bB}	99.21 ± 1.01^{aB}	92.52 ± 0.58^{cB}
	FPC20	103.63 ± 0.46^{aA}	86.35 ± 0.87^{dA}	99.35 ± 0.47^{bA}	103.32 ± 0.84^{aA}	95.53 ± 0.91^{cA}
CM (%)	FPF	15.46 ± 0.35^{aA}	10.89 ± 0.96^{bA}	9.69 ± 0.48^{cA}	8.88 ± 0.19^{dA}	10.53 ± 0.47^{bA}
	FPC10	9.15 ± 0.66^{aB}	7.86 ± 0.57^{cB}	6.92 ± 0.71^{dB}	6.29 ± 0.63^{dB}	8.21 ± 0.37^{bB}
	FPC15	8.92 ± 0.40^{aB}	8.08 ± 0.42^{aB}	6.49 ± 0.54^{bB}	6.15 ± 0.64^{bB}	8.17 ± 0.42^{aB}
	FPC20	8.72 ± 0.27^{aB}	7.93 ± 0.43^{bB}	6.15 ± 0.72^{cB}	5.71 ± 0.27^{dC}	7.67 ± 0.26^{bB}
H/L	FPF	3.09	3.83	2.96	2.52	3.17
	FPC10	3.98	4.10	3.82	3.77	4.14
	FPC15	3.87	4.62	3.73	3.64	4.78
	FPC20	3.85	4.48	3.68	3.44	4.08

These values are the means of three tests for each parameter. The mean ± SD, with different lower case letters in the same line is significantly different ($p < 0.05$) according to Tukey. The mean ± SD, with different uppercase letters in the same column indicates a significant difference according to the Tukey test.

CONCLUSION

The flour of each of these five local plantain cultivars has excellent functional properties overall. Nevertheless, the flours of the raw and cooked pulp of the Afoto cultivar have both the highest oil absorption capacity, the best foam stability and the high swelling and solubility in water. In addition, the raw pulp flour of this same cultivar has the highest water absorption capacity and has the best foaming capacity. The functional properties of the flours of all these cultivars, improve considerably with the cooking with the water of the pulp. In view of these functional properties, it is obvious that these flours can be used in pastry, bakery and also for the preparation of food porridge.

COMPETING INTERESTS

The authors declare that they have no competing interests.

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